Tiered Implementation of the Chesapeake Bay TMDL: A STAC Prospectus

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Contents

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The Scientific and Technical Advisory Committee (STAC) provides scientific and technical guidance to the Chesapeake Bay Program (CBP) on measures to restore and protect the Chesapeake Bay. Since its creation in December 1984, STAC has worked to enhance scientific communication and outreach throughout the Chesapeake Bay Watershed and beyond. STAC provides scientific and technical advice in various ways, including (1) technical reports and papers, (2) discussion groups, (3) assistance in organizing merit reviews of CBP programs and projects, (4) technical workshops, and (5) interaction between STAC members and the CBP. Through professional and academic contacts and organizational networks of its members, STAC ensures close cooperation among and between the various research institutions and management agencies represented in the Watershed. For additional information about STAC, please visit the STAC website at www.chesapeake.org/stac.

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This Prospectus is an outreach product of the Comprehensive Evaluation of System Response (CESR) report, released in May of 2023. CESR identified a range of opportunities for improved effectiveness in achieving the goals of the 2014 Watershed Agreement and the Beyond 2025 planning project. This prospectus is the first of an intended series of outreach products that provide more detailed descriptions of what these opportunities could look like if integrated into current partnership efforts. To that end, we would like to especially thank our partners from the Chesapeake Bay partnership who provided guidance and consultation to ensure that the prospectus was grounded in potential management and policy: Lee McDonnell (US EPA), Gary Shenk (USGS) and Mark Monaco (NOAA).

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Introduction

Reducing nutrient loads to improve water quality conditions in the Chesapeake Bay has been a central focus of the Chesapeake Bay Program partnership for 40 years. In 2009, the Chesapeake Bay Total Maximum Daily Load (TMDL) formally established nitrogen, phosphorus, and sediment loading targets designed to meet all numeric Bay water quality criteria for dissolved oxygen, water clarity/submerged aquatic vegetation (SAV), and Chlorophyll-a (Chl-a). Numeric water quality criteria are established to support the designated use of enhancing and protecting living resources. Nutrient reduction targets have been set to meet the dissolved oxygen criteria across the Bay, the magnitude of the targets is driven by the areas where oxygen levels are the lowest and most challenging to improve: the deep water habitats in the mainstem of the Bay. The STAC Comprehensive Evaluation of System Response (CESR) report (2023) concludes that the 100% achievement of the complete set of water quality criteria will take longer and be more challenging than originally anticipated in 2009 (STAC 2023, vii-viii, 76). The report highlights a variety of reasons for this conclusion including the challenges, costs, and uncertainties associated with reducing nutrient nonpoint sources; uncertainties in watershed and estuary responses to reductions; and the impacts of warming temperatures, precipitation changes, and sea level rise, which are shifting the underlying biophysical conditions of the Bay.

The CESR report recommends directing more management attention to the primary reason for establishing water quality goals: improving Bay living resources. It notes that the Chesapeake Bay Program’s technical analyses, staff time, and financial resources have traditionally been focused on Clean Water Act compliance, particularly dissolved oxygen in the main channel deep water habitats. This focus has limited the effort and financial resources available for incorporating living resource considerations–beyond the achievement of the states’ Chesapeake Bay water quality standards–into both the TMDL and other Chesapeake Bay Program activities (STAC 2023, p. ix, 77). The CESR report identifies opportunities to link water quality management decisions more closely to potential improvements in tidal living resource responses. For example, habitat suitability analyses, as described in CESR and supporting documents, can identify where water quality investments are likely to provide the most significant improvements to living resource habitat conditions. These analyses can also identify additional actions that can elevate living resource habitat, further advancing the designated use of the bay (STAC 2023; Rose et al. 2023).

In light of these two findings, the CESR report proposes a tiered approach to implementing the TMDL (STAC 2023, pp.82-83). A “tiered TMDL” upholds the entirety of current Bay water quality standards and maintains the overall TMDL nutrient reduction targets but offers an alternative path toward attainment. *A tiered approach to TMDL implementation establishes a staggered timeline, with interim goals that prioritize pollutant load reductions to local (segment/habitat) regions of the Bay that can provide the greatest anticipated benefit to living resources.*[1] The tiered approach is based on the premise that the location of water quality improvements will have varying impacts on living resources. While still moving toward final TMDL goals, a tiered approach directs near term planning and implementation of nutrient and

[1] For purpose of this document, the term “local” is defined as a segment/habitat combination given existing 92 Bay segments and 5 habitats.

sediment reduction efforts to areas with the most potential to improve Bay living resources.[2] With a broader planning focus coupled with additional habitat suitability tools, a tiered implementation of the TMDL could also identify other opportunities besides those associated with nutrient and sediment load reductions that can improve living resource response to our water quality investments. Finally, the shift to a more local planning focus could create opportunities to improve our understanding of how management actions translate into desired outcomes and to use that learning to better tailor implementation plans to local conditions (see Table 1 for a summary).

Table 1: Approaches to Implementing the Chesapeake Bay TMDL

	Tiered Approach	**Conventional Approach**
What are planning priorities for nutrient reduction?	Local areas for living resource benefit	Deep channel dissolved oxygen in the mainstem of the Bay
What type of implementation?	Water quality + habitat restoration	Water quality
What is the implementation horizon?	10-15 yrs for interim goals	10-15 yrs for final TMDL target
How is implementation success evaluated?	Model response and monitoring at local scale	Model response
What are final TMDL nutrient and sediment targets?	Same	Same
What are TMDL permittee obligations?	Same	Same

Table 1. Comparison of tiered and conventional approaches to implementing the Chesapeake Bay TMDL, highlighting differences in planning priorities, implementation strategies, and evaluation methods.

Tiering TMDL implementation around potential living resource response is an adaptive management advancement in Chesapeake Bay water quality planning and management. The purpose of this prospectus is to provide a general description a tiered approach to Bay TMDL implementation. The intent is to present a technically and administratively feasible version of how TMDL implementation could proceed in the next phase of efforts to achieve Bay water quality goals while simultaneously providing additional improvements in living resource habitat conditions where they are most needed.

[2] A tiered approach also does not change the nutrient wasteload allocations of point source permittees since these limits are required to be consistent with water quality standards and large majority of those limits have (or soon will be) achieved. The planning focus is on how to stage and better geographically target efforts to meet the unmet nutrient and sediment load reductions in the most effective way possible to maximize tidal living resource habitat conditions.

Chesapeake Bay Water Quality Standards and Approaches to Implementing the TMDL

Water Quality Standards. The Chesapeake Bay water quality standards (WQS) establish Bay living resources as the ultimate "designated use" of the estuary. The WQS also establish numeric water quality criteria necessary for supporting living resources. Water quality criteria for the entire Bay include dissolved oxygen, water clarity, and, to a limited extent, chlorophyll-a across five defined habitats: open water, deep water, deep channel, migratory spawning, and shallow water. The Bay is further divided into 92 spatial segments, with each being assigned up to five habitat types, as appropriate (Figure 1). Thus, full attainment of the Bay water quality goals means attaining multiple dissolved oxygen, water clarity, and Chl-a criteria in 5 different habitats, and across 92 different regions (segments) of the Bay.

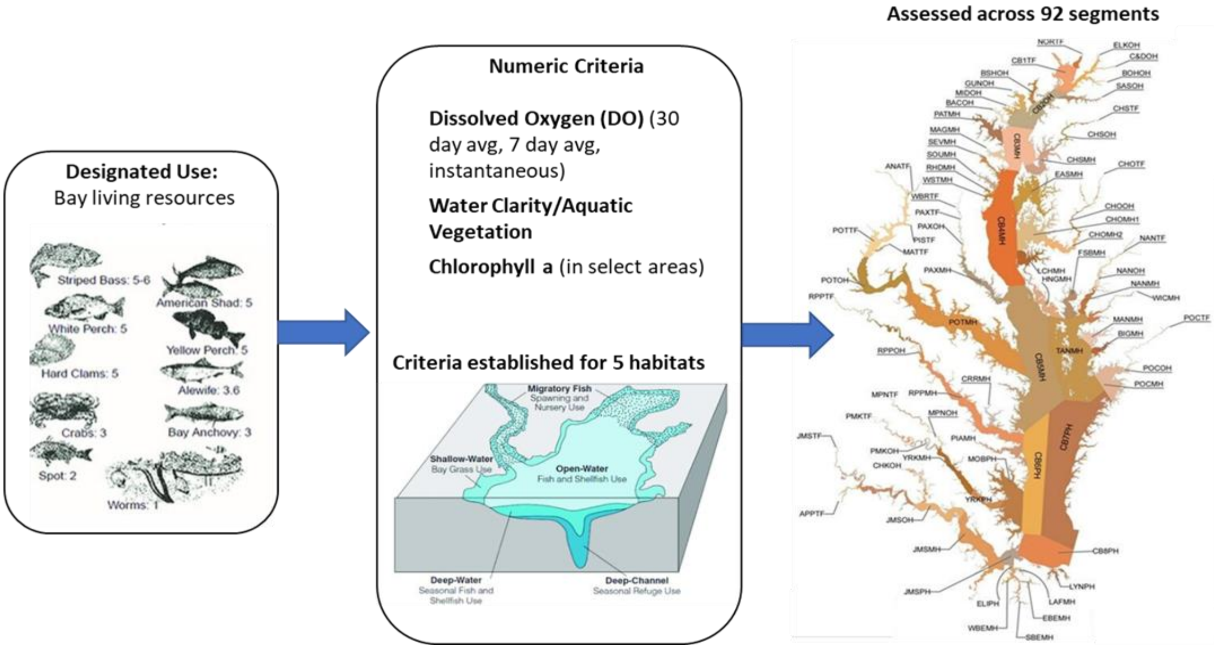


Figure 1. Chesapeake Bay Water Quality Standards.

Current Approach to Implementing the TMDL. The Chesapeake Bay TMDL establishes nutrient and sediment load targets that are predicted to meet the water quality criteria across all habitats and segments.[3] The TMDL nutrient load targets were established to attain the dissolved oxygen criteria in the regions of the Bay that are the most challenging to achieve: deep-water habitats in the middle segments of the main channel in the Bay. Specifically, the segments are CB3, CB4, CB5, and POTMH (See Figure 2), and the percentage of the total volume of water in each of these segments that is considered deep channel habitat is 5%, 26%, 52%, and 14%, respectively. These areas of the Bay are the most susceptible to summer hypoxia and estuary modeling suggests these specific habitats/segments require the largest load reductions to reach attainment status relative to the other habitats. Notably, millions of pounds of additional nitrogen

[3] Current TMDL targets for total nitrogen, total phosphorus, and sediment are 194, 12.7, and 18,587 million pounds per year, respectively.

and phosphorus reductions are necessary to bring main channel deep water habitats into attainment. The premise of the current approach to implementing the TMDL is that setting and achieving nutrient load targets at levels to meet deep water dissolved oxygen (DO) criteria will be sufficient to meet water quality criteria across all habitats.

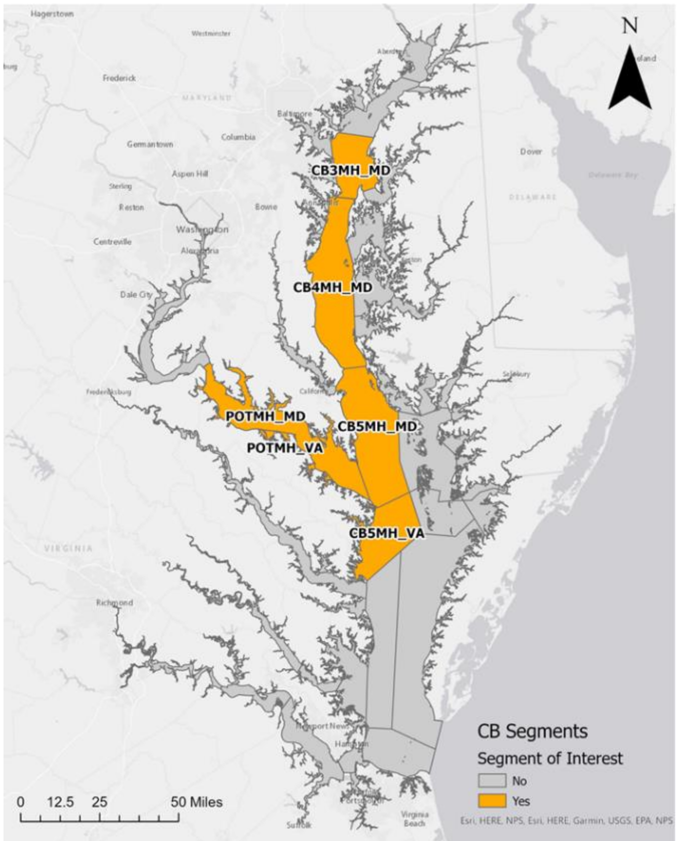


Figure 3. Focal Chesapeake Bay segments (CB3, CB4, CB5, and Potomac) and deep water/deep channel habitats for setting final TMDL targets.

TMDL planning evaluates nutrient load reductions across the watershed relative to their contribution to bringing the main channel deep water habitats into attainment. Southern tributaries, such as the York and James, have a relatively small impact on low DO conditions in CB3, CB4, and CB5. The Susquehanna, Potomac, and coastal watersheds, however, have a disproportionately larger impact on DO conditions in main channel deep waters. In other words, a pound of nitrogen (N) from the Susquehanna will have a much larger impact on DO in the main channel than a pound of N from the James River. Nitrogen and phosphorus (P) loads can be modeled using "eutrophication units" which convert pollutant loads to DO impact in these targeted areas. The assignment of nutrient load reduction targets to the jurisdictions is driven by the relative impact of these nutrients on main channel deep water DO.

Chesapeake Bay Program partners agreed to implement management actions predicted to achieve the TMDL nutrient and sediment load targets by 2025. States submitted Watershed Implementation Plans (WIPs) that described the type and level of management actions (e.g., Best Management Practices) needed to meet those nutrient reduction goals. The development of individual WIPs relies on the CBP's watershed modeling tools to predict the nutrient reduction effectiveness of management actions on deep water DO.[4]

[4] The TMDL process described above is conceptually similar to past efforts to achieve Chesapeake Water quality goals. The 1987/1992 watershed agreement established a 40% nutrient reduction goal to achieved Bay water quality goals by 2000. The 2000 agreement established another 10-year goal to achieve final nutrient and sediment goals needed to meet water quality standards.

Tiered Approach to Implementing the TMDL. A tiered implementation of the TMDL would continue to pursue nutrient load reductions toward the final TMDL targets but would prioritize nutrient load reductions in areas where water quality conditions are both most responsive to nutrient reductions and offer habitats that would most improve living resources. The tiered approach is based on the premise that water quality improvements in different regions of the Bay have different potential impacts on living resources. For example, water quality improvements in certain open water and shallow water habitats can provide more direct benefits to many key fish species (forage fish, recreational/ commercial species, etc.) than improvements in deep water habitats. Figure 3 shows an example of a past effort to prioritize regions of the Bay for water quality improvement based on potential impacts to target species. Note that many tributaries and Bay inlets were ranked as high priority for supporting the largest diversity of species, like spot, speckled sea trout, flounder, shad, menhaden and bay anchovy, over deep water habitats in the main channel.

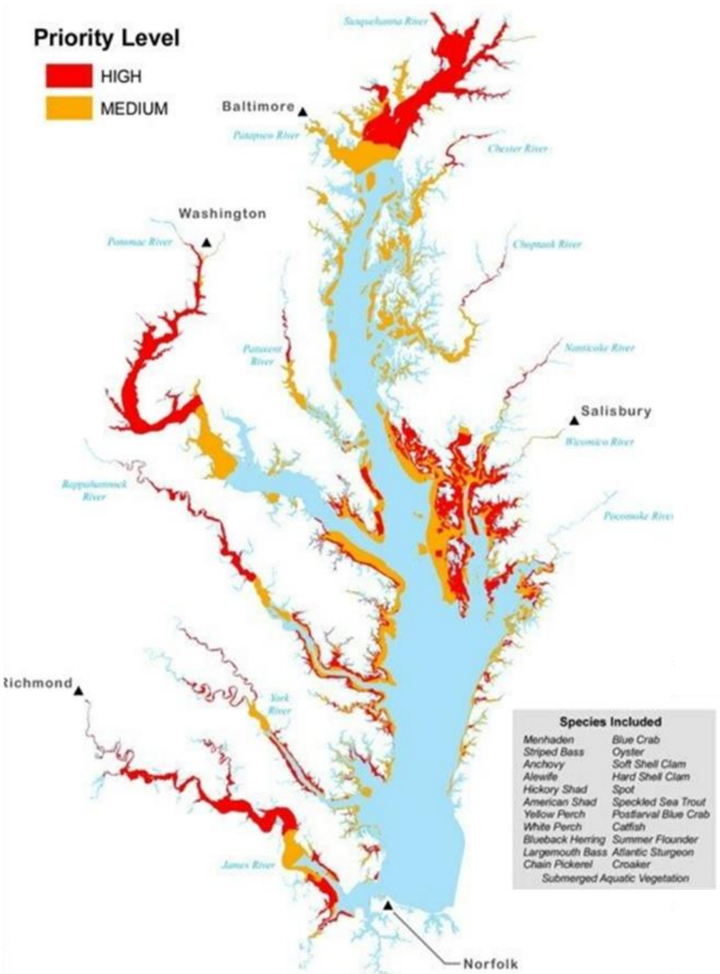


Figure 8. Example of Chesapeake Bay regions prioritized based on potential living resource impact (Source: Chesapeake Bay Program, 2009).

Under a tiered approach to implementation, areas where water quality improvements have the most potential to boost living resource response in the short term would be prioritized for more aggressive management efforts. As explained below, nutrient reductions to support these important local water quality improvements will often need to come from both local and regional sources. The premise of tiered TMDL implementation is that achieving nutrient and sediment load reductions to these areas to maximize living resource potential would also ultimately provide dissolved oxygen benefits in the deep waters. Planning and management at smaller scales creates opportunities to better engage stakeholders in water quality management, to address and understand uncertainties in watershed and estuary responses to management efforts, and to increase attention to tracking and documenting outcomes.

Components of a Tiered Approach to Implementing the TMDL

A tiered approach to implementing the TMDL involves:

1. Identifying areas and opportunities to enhance Bay living resources, considering not only water quality but also other important habitat factors that can improve living resource response in localized areas.
2. Assessing local water quality response to nutrient and sediment stressors, with evaluations conducted at the scale of the 92 spatial segments used for TMDL assessments.
3. Determining the sources of nutrient and sediment loads on localized water quality.

This approach would complement existing data and modeling tools by incorporating additional and diverse data sources, along with analytical tools best suited for localized assessments.

Identify areas and opportunities for improving Bay living resources. A tiered approach to TMDL implementation requires identifying areas and habitats in the Bay where changes to water quality conditions have the most potential to improve living resource habitats (and ideally the abundance, resilience, and diversity of living resources themselves). This process would include identifying habitat factors (including but not limited to water quality) that are important to the life stages of key species living in the Bay, assessing the current status of those factors in the localized areas of the Bay, and then assessing the potential to improve the status of those factors in localized areas. The analysis to support this process is largely yet to be done and would require a combination of additional data and modeling activities. A well-established scientific literature exists to identify the habitat conditions that support the life cycles of different species. Habitat models have been developed and applied for many Chesapeake Bay species (e.g., Fabrizio et al. 2020, Secor 2009, Schlenger et al. 2022). Habitat models statistically relate observed local densities or abundances of life stages of specific species of fish and shellfish to the presence of environmental and water quality variables in near proximity. The presence and abundance of a Bay fish species/life stage has been associated with a number of factors, including water quality variables such as dissolved oxygen, salinity, temperature, pH, chlorophyll, and water clarity, but also physical habitat variables such as shoreline conditions (e.g., percentage of hardened shoreline), bottom type and condition, water depth and speed, and presence of various aquatic habitat types (oyster reefs, marsh, submerged aquatic vegetation). Habitat analyses reveal differences in sensitivities to habitat factors across species. Some species will be more sensitive to changes in water quality, while other species, such as several species of forage fish, are particularly sensitive to the condition of near shore habitats (hardened shorelines) (Rose et al. 2023). Trade-offs among species may also exist. For example, some fish species at the base of the food chain thrive at higher levels of primary production (which is stimulated by higher nutrient levels). Such trade-offs and distinctions must be acknowledged and managed under a tiered approach.

Habitat models identify the conditions that provide the most *potential* to improve species abundance but do not purport to predict the abundance of specific species if habitat conditions improve in a particular way. Changes in densities or abundances are not necessarily proportional to changes in habitat availability, although an operating principle is that more high-quality habitat is better. Habitat suitability has the advantage over predictions of abundance and diversity of being relatively simple and estimated from available data. Predictions of population and food web responses would be more closely relevant to management decisions but involve much more uncertainty than habitat analyses. STAC proposes the use of habitat suitability analysis in the context of tiered implementation of the TMDL as the best balance between relevance to management and uncertainty.

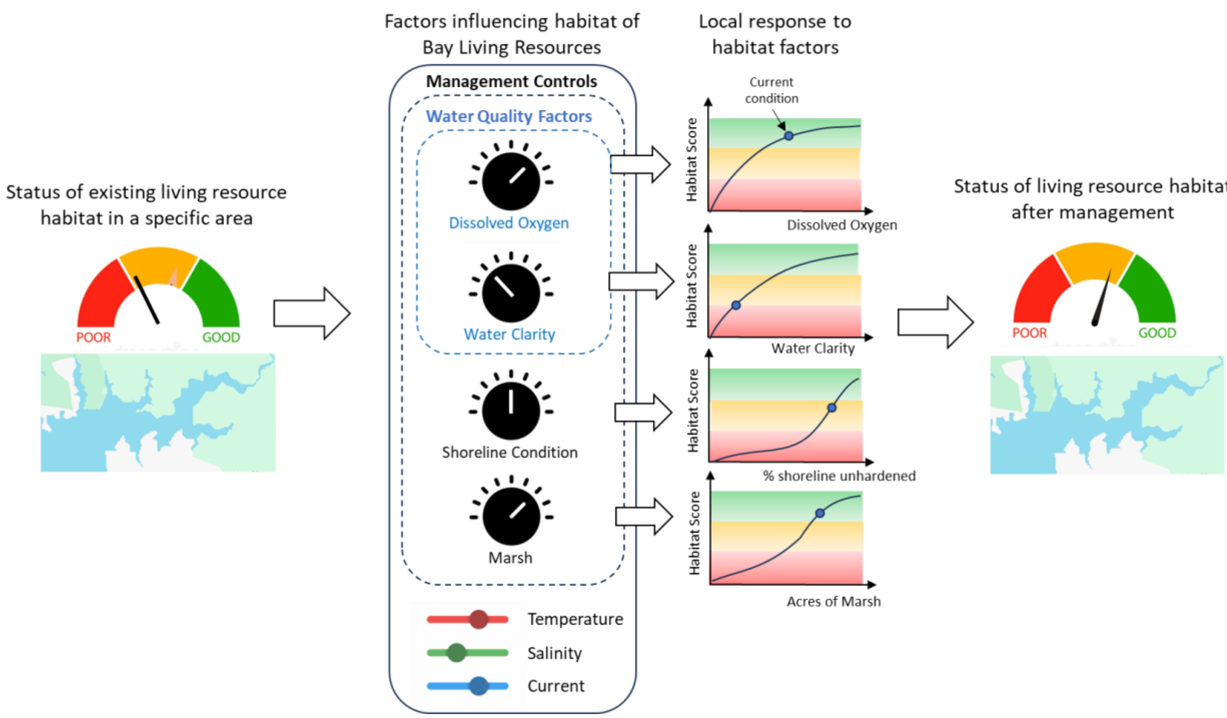


Figure 15. Process for identifying factors that improve Bay living resource habitat.

Such analyses are foundational to evaluate the potential influence of habitat factors for a collection of species. Each area of the Bay (defined as one of the 92 segments) will likely have the same factors important to habitat suitability for each life stage/species combination, but the values of these factors will vary among segments. Some of these factors, such as DO and water clarity, are directly managed under the TMDL (represented by "dials" in Figure 4). The extent to which nutrient and sediment loads can improve water quality conditions (e.g., turn the "dial" in Figure 4) varies by location. Other factors can significantly improve living resource habitat (e.g., shoreline conditions and tidal wetlands) but are not managed directly under the TMDL[5], though they are still subject to management control (also represented by "dials" in Figure 4). Factors largely outside of direct management control, such as temperature, salinity, and current, can have a large impact on living resources (represented by bars in Figure 4). The habitat factors under management control can be evaluated to identify places where management can change the status of the habitat factors and convert poor habitat to medium habitat and/or medium habitat to good habitat.

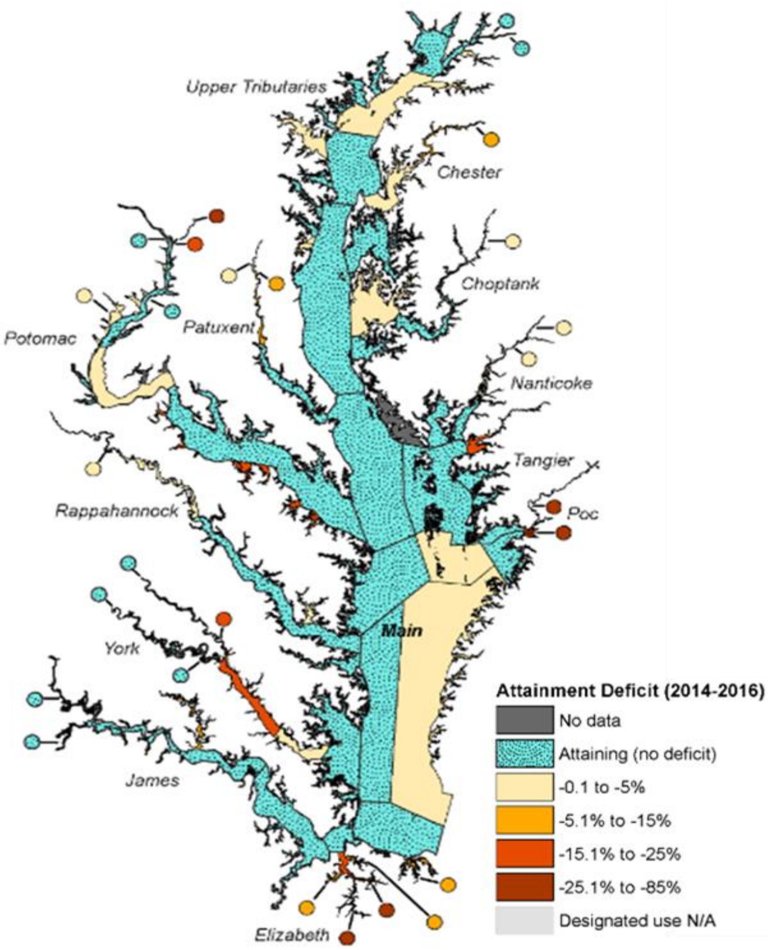
[5] Figure 4 shows an illustrative, but not comprehensive, set of habitat factors.

Within a tiered implementation of the TMDL, the key management challenge is to identify and prioritize areas where improvements in water quality conditions, such as dissolved oxygen, water clarity, and/or chlorophyll-a, have the most potential to improve living resource habitat conditions for the Bay (See Figure 4). Segments of the Bay where improvement in water quality conditions (areas of nonattainment) could "move the needle" in terms of living resource potential would be considered high priority target areas (left- and right-hand graphics in Figure 4). For TMDL-related water quality investments to improve habitat conditions, it is necessary to consider whether: 1) Nutrient and sediment reductions will make an appreciable improvement in water quality conditions (move blue dot to the right on the horizontal axes in Figure 4);, and 2) Whether these changes in water quality will produce appreciable improvements in living resource habitat conditions in that local area (to increase living resource habitat on vertical axes in Figure 4).

The hypothetical representation of a localized area in Figure 4 shows that dissolved oxygen levels at this location are generally good and further improvements in DO levels would not substantially improve living resource habitat. However, Figure 4 also shows that improvements in water clarity could make notable improvements in habitat. Other areas may have different water quality conditions, where local improvements in DO will substantially improve habitat. In both situations, these areas would be prioritized for nutrient and sediment reductions since the habitat analysis finds substantial potential to improve habitat conditions.

In other segments, improvements in water quality conditions may have limited potential to improve localized living resource habitats, either because water quality conditions are sufficient or because living resources are limited instead by physical habitat conditions (poor bottom conditions, poor marsh conditions, shoreline conditions, etc.). The extent to which improvements in local dissolved oxygen and water clarity conditions could improve living resource potential differs across the Bay. Figure 5 shows the level and status of key water quality indicators across the Bay and illustrates that open water and shallow regions along the edges and in the tributaries still have significant DO challenges. Where these areas overlap with areas deemed important for target species, opportunities can be identified where localized water quality improvements could potentially improve living resource habitat.

Assess local water quality response to nutrient and sediment stressors. Local areas of the Bay can be quite different and are characterized by unique conditions and sets of stressors. A tiered approach to implementation would devote planning and analytical effort to assessing how pollutant loads respond to management efforts and how local water quality responds to changes in pollutant loads. Additional analysis may be required since larger-scale models will not completely or accurately capture adequate levels of detail and are characterized by uncertainty at small scales. For instance, some regions of the Bay show increasing nutrient loads despite predicted declines. In certain areas, dissolved oxygen may respond unpredictably to nutrient reductions, and aquatic grasses may recover even without improvements in Chl-a or nutrient levels. Large-scale estuary models may fail to fully capture critical local patterns, such as dissolved oxygen diurnal cycles in shallow water habitats vital to key species. To address these gaps, additional models, enhanced monitoring, or expert judgment may be necessary to better understand stressor-response relationships and address conflicting trends or uncertainties. Assessment should also consider the cost and feasibility of achieving different levels of local pollutant reductions, i.e., how difficult and/or costly is it to "turn the dials"? This will depend upon the results of the next step.



Open Water DO Attainment Status, 2014-16
(Source: Zhang et al. 2018)

Figure 22. Examples of Bay segments not attaining open water DO.

Identify the source and effect of nutrient and sediment loads on local water quality. If localized nutrient and sediment reductions have the potential to improve habitat conditions in individual segments, then the next step is to identify the source of the nutrients and sediment. Nutrient levels in any given Bay segment are comprised of both "upstream" nutrients (nutrients contributed by the watershed upstream of the segment) and "estuarine" sourced nutrients (e.g., nutrients that enter the Bay segment from the estuary itself). The influence of upstream conditions on local water quality varies predictably by location across the Bay's 92 segments. For instance, upstream sources typically dominate water quality conditions in the oligohaline (low salinity) segments (e.g., nutrients in the upper tidal segments of the Rappahannock River come primarily from the Rappahannock watershed). In contrast, water quality in mesohaline and polyhaline segments is primarily influenced by estuarine source nutrients. This means to improve water quality in these areas, it is necessary to achieve nutrient reductions from other regions of the Bay. For example, nutrients in many Eastern Shore segments in the middle section of the Bay primarily originate from the Susquehanna. Acknowledging these physical realities is essential to estimate where management actions are needed to improve local water quality and living resource habitats, and to ascertain how difficult it will be to "turn the dial" of water quality conditions.

Moving from Concept to Implementation

A tiered implementation serves as an intermediate step toward attainment of Bay water quality standards. This approach establishes interim nutrient targets aimed at enhancing important living resource habitats in specific areas of the Bay. These interim targets are more achievable within a 10–15-year timeframe and are likely to have a more significant impact on living resources. However, to implement a tiered approach, it requires modification and adoption of new tools and planning processes. The planning process must assess segment/habitats on their potential to support aquatic species, and where water quality conditions are important to habitat quality, identify opportunities at the segment-habitat level that can most improve living resource habitats, establish indicators that ensure habitat improvements are achieved, and allocate nutrient and sediment reductions necessary to meet these habitat improvement goals. This section outlines the steps and issues that would need to be integrated into the water quality management and decision-making process to operationalize the approach.

1. **Conduct habitat suitability analyses for key living resource species for each of the 92 segments**. Habitat suitability analyses would be used to identify locations of priority living resource habitats, similar to the outcomes shown in Figure 3. The process would involve selection of key species to include in the assessment. Selected species would represent a diversity of species across the food chain and include species with different habitat sensitivities. Water quality managers would make collective judgments, potentially aided by decision support processes, to collaboratively develop an approach to assign an overall habitat suitability score to each segment-habitat combination.

2. **Assess living resource habitat improvement potential from changes in water quality and other habitat factors.** Once important habitats are identified, local conditions in each segment are evaluated to determine the potential for management actions to improve habitats. Segment-habitat combinations are prioritized based on the potential for water quality improvements (dissolved oxygen, water clarity, or Chl-a) to enhance habitat quality. Some segment-habitats may be ranked as having low improvement potential because either water conditions (e.g., DO and water clarity) are already good (attaining) or because living resource habitat and response are dominated by other habitat factors that may be limiting living resource response independent of water quality conditions.

Together, steps 1 and 2 identify where water quality improvements (at the Bay segment-habitat level) have the most potential to improve living resource habitat conditions. A hypothetical illustration of what this process could produce is shown in Figure 6-a. The areas identified with the gauge icon show areas where local water quality improvements (DO or water clarity have the potential to "move the habitat needle."

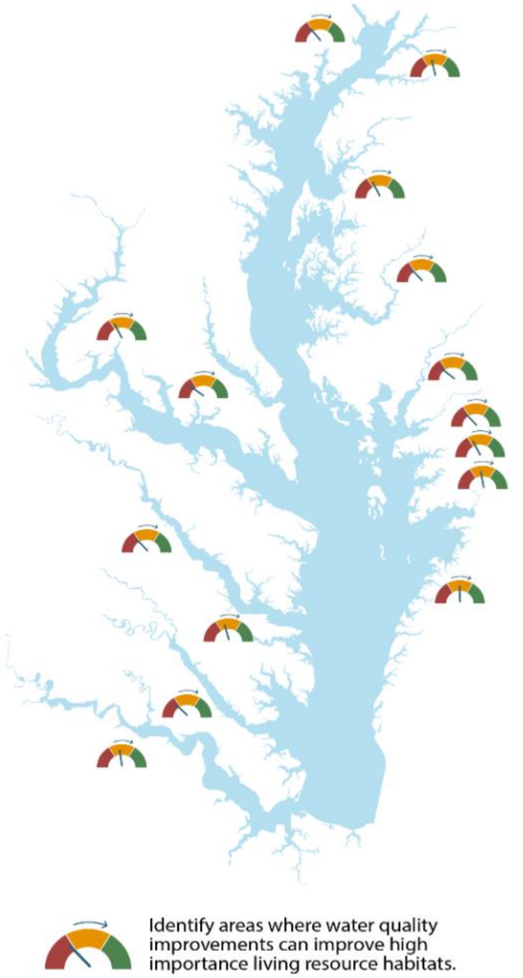


Figure 6- a. Hypothetical illustrative outcome of a process to identify priority segment-habitats where water quality improvements can improve in high importance living

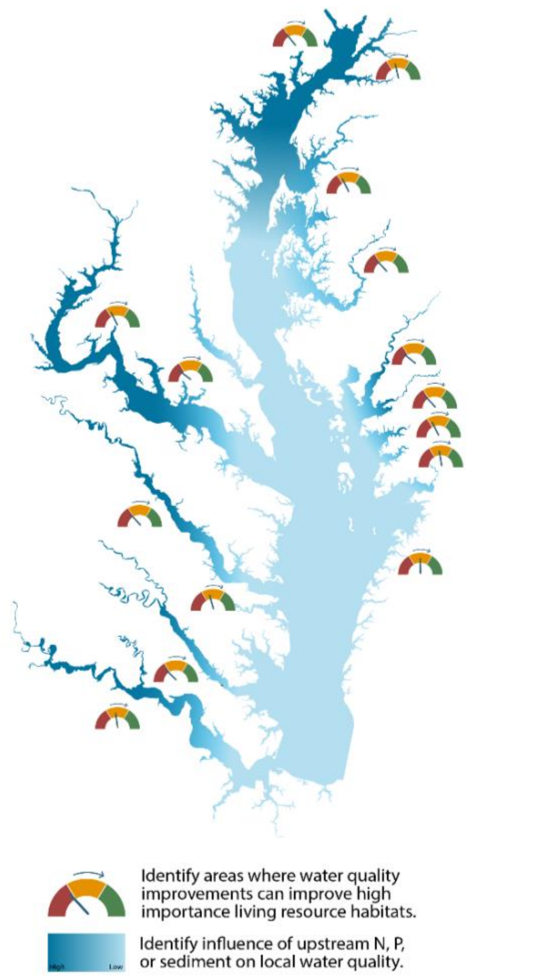


Figure 6- a. Hypothetical illustration of the influence of upstream N, P or sediment on local water quality in priority areas. Darker blue shading illustrates greater influence of upstream sources of nutrients on local water quality. Lighter blue shading signifies less upstream influence and more regional (estuarine) influence.

3. **Identify relative contribution of upstream and estuarine N, P and sediment on segment-habitat nutrient levels.** The next step is to determine where and how nutrient and sediment reductions can produce water quality improvements in priority habitats (see a hypothetical illustration in Figure 6-b). The tiered approach requires answering the technical question: What spatial distribution of nutrient load reductions ('X') can produce specific water quality improvements ('Y') and corresponding habitat enhancements in a segment? As previously noted, the contributions of upstream and estuarine N, P and sediment to local water quality

vary across the Bay. In Figure 6-b, darker blue shading shows the influence of upstream nutrients on the local water quality, while the lighter blue shading (e.g., near the Eastern Shore) reflects areas where estuarine sources dominate. Thus, achieving water quality goals in segments with high potential for habitat improvements often requires nutrient and sediment reductions across multiple areas/tributaries. While the next generation of the CBP estuarine model offers finer-scale estimates of water quality responses to nutrient and sediment inputs, developing localized models tailored to specific segment responses should also be considered.

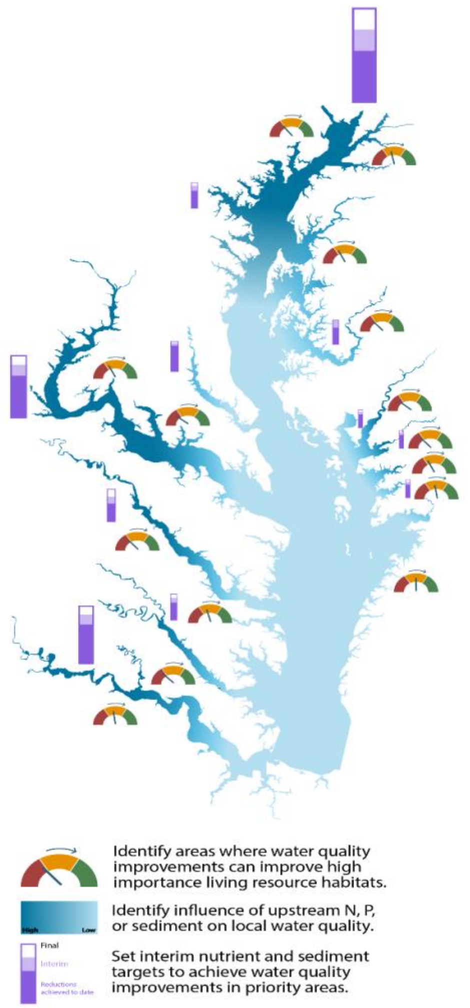


Figure 6- b. Hypothetical illustration of showing interim nutrient targets across the watershed. The purple bars illustrate interim nutrient and sediment targets (light purple) relative to reductions achieved to date (dark purple) and final TMDL targets (top of the bar).

4. **Establish interim nutrient and sediment targets across the regions of the Bay to achieve the necessary water quality improvements in high impact habitats**. Various combinations of local and tributary nutrient load reductions could achieve water quality improvements in priority areas. Bay jurisdictions would establish a planning process, supported by the tools above, to identify equitable and cost-effective interim nutrient and sediment targets (see Figure 6-c for a hypothetical illustration). These locally derived interim targets are likely to be less stringent than the nutrient and sediment goals established under the 2010 TMDL process and associated WIPs, in recognition that living resource benefits can be achieved without full attainment of all water quality standards. [6] While the interim reduction targets are not expected to achieve full compliance with the TMDL, they will continue to improve summer deep channel hypoxia.

5. **A tiered approach to TMDL implementation would be strengthened by a watershed implementation process that adaptively manages local water quality response.** The tiered approach to TMDL implementation requires the

[6] For example, interim nutrients and sediment targets in the Susquehanna may be well below what is required in the TMDL. Nutrient and sediments from the Susquehanna have a large influence on both shallow/open water habitats in the upper bay and on main channel deep water DO. However, it is likely that improvements in priority living

ability to adapt management strategies based on learning about the connections between management actions, load reductions, water quality changes, and habitat conditions at a more local level. Local shallow water habitats are diverse and less well understood compared to deep water hypoxia in the main channel. When moving to finer spatial scales, there are often divergences between predicted and observed outcomes.[7] Many of the clear examples of water quality improvements associated with nutrient load reductions have been in shallow water tributaries, but in all of those cases, nutrient load reductions were among the highest achieved in the Bay and came via reduced wastewater treatment plant loads (Back River, Mattawoman Creek). In contrast, focused restoration efforts targeting nonpoint sources in some watersheds of small tributaries (e.g., Corsica River estuary) have not always yielded substantial nutrient load reductions or water quality improvement.

In short, uncertainty exists in system response: how implementation translates into load reductions, and how load reductions translate into improvements in local water quality conditions. The CESR report stressed the importance of localized monitoring to improving understanding of system response and accountability. An accountability system that relies too heavily on model predictions to document progress can obscure discrepancies in system response, reduce incentives for local monitoring, and delay development of more effective implementation strategies (STAC 2023). A tiered approach to TMDL implementation would be strengthened by creating incentives and incorporating local indicators and monitoring that would promote and encourage learning and help determine how management can lead to desired outcomes.

6. **Devise a future watershed implementation process that incorporates local habitat factors into the planning process.** A tiered approach should encourage jurisdictions located in segments with priority living resource habitat to pursue improvements that would generate the greatest potential impact on living resources. For example, the habitat suitability analysis might show that improving physical habitats (such as marshes, softening shorelines) could have a larger potential impact on living resources than focusing solely on water quality. In such cases, jurisdictions could be allowed to temporarily scale back nutrient and sediment efforts during the interim period if other restoration activities can reasonably be expected to generate greater benefits for living resources. For instance, a local jurisdiction may determine that additional nutrient reductions in the near term would be costly, produce only modest improvements in water quality, and have limited effects on local habitat. However, the jurisdiction may be willing and able to improve near shore habitats (e.g., marsh expansion) or pursue more aggressive efforts to prevent shoreline hardening in areas with high quality habitat. A tiered approach would also give jurisdictions the flexibility to evaluate and pursue temporal and spatial trade-offs to achieve a greater return on investment in living resources. It should be noted that some habitat improvements may be vulnerable to year-to-year changes in freshwater inflow, salinity, temperature, and other factors and thus their longevity

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resource habitats in the upper portions of the Bay can be achieved with substantially fewer Susquehanna nutrient and sediment reductions than what would be required to full attain deep channel DO goals.

[7] For instance, the CBP CAST model predicts that N and P loads are declining or flat over the past 20 years in many localized areas of the Coastal Plain but monitoring shows significant upward trends in nutrient and sediment loads (STAC 2023; Easton et al. 2023).

is uncertain. These risks should be considered in planning a wider range of habitat restoration approaches.

Conclusion

STAC is confident that the necessary technical tools and scientific knowledge are available to implement such an approach, but acknowledges that doing so would require a commitment of time and effort by the Bay partnership. Specifically, the tiered approach focuses interim TMDL planning and implementation on prioritizing pollutant control efforts based on their potential to improve living resource habitats. The approach would require additional modeling and monitoring for shallow water habitats, which are critical living resource habitats in the Bay. The approach also cannot guarantee that all anticipated local water quality outcomes would be realized within the planning period. Like Bay water quality management in general, uncertainties exist regarding whether management efforts will be translated into load reductions and local water quality response.

The potential for a tiered approach to accelerate living resource improvements and boost implementation effectiveness is considerable. Rather than detracting from the overall TMDL goal, the tiered approach is designed to maximize the living resource impact of additional nutrient reductions at a time when further pollutant reductions are becoming increasingly costly and difficult to achieve. Focusing on local water quality improvements creates new opportunities to deepen our collective understanding of the link between implementation and water quality outcomes. A tiered approach would require nutrient reductions across the watershed to achieve localized water quality improvements, thus furthering progress towards the final TMDL goals and improving deep water DO. Finally, the tiered implementation approach fosters the connection of people and communities to the ultimate goal of sustaining Chesapeake Bay living resources.

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